9th Annual EPRI-IEA Challenges in Decarbonization Workshop
A window into the global energy transition

Session 2: Electricity market design for high renewable systems

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Need for the evolution of power markets

*To support the energy transition towards net zero carbon systems*

Power market design is an important tool that can’t be considered in isolation

- Clean and alternative fuel incentives and feed in tariffs
- Carbon pricing mechanisms
- Cross sector coupling
- Consumer protection

Requirements for successful competitive power markets

- Incentivize performance (system, plant level) and needed characteristics
- Adequately pay for needed longer-term plant investments
- Ensure reliability, stability and resilience and drive system efficiencies

Remuneration mechanisms to promote resource investment and operational signals for the energy transition
Electric power systems operated to least cost

Economics and location of physical assets drive operations

**PHYSICS**
... maintain frequency and voltage

**BALANCING**
... deliver enough power to meet demand

**ANCILLARY/SUPPORT SERVICES**
- Inertia
- Governor response
- Regulation
- Real time/balancing
- Day ahead

**CAPACITY**
- Grid operator controlled

**Stability**
Energy Deliverability
Adequacy

**SECONDS**
**HOURS**
**YEARS**

Electricity Market Design | 6 October 2022
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Energy price mechanisms

Marginal energy prices pay as clear, reflecting least cost of efficient operation

- Promote market liquidity and price transparency
- Provide for creation of hedging instruments
- Price foundation for PPAs and CfDs
- Reflect externalities i.e., carbon pricing

As demand varies, grid operators dispatch the next best alternative based on variable cost.

Increased renewables

Increased gas prices
Locational marginal prices (LMP)

Reflect security constrained dispatch

- ZONAL
  Lower resolution
  ~200 MB
  ~20 zonal prices
  ~20 hub gas prices

- NODAL
  Higher resolution
  ~2 TB
  ~1,000 nodal prices
  ~50 plant gas prices

- Inter-zone constraints
- Timescale groups
- Lower computational need, less data intensive
- Less reflective of locational oversupply and scarcity pricing

Zonal estimate
$29/MWH
$27

Actual LMP
$22/MWH
$34

Ref: Hitachi ABB Ventyx
e.g., PJM, '17 annual average prices

~1,000 nodal prices
~50 plant gas prices

~2 TB
Typical 20 yr. simulation (PJM, Eastern interconnection)

- Full transmission constraints
- Timescale granularity
- High computational need
- Location of oversupply and scarcity
- Signals for location of new generation, transmission (& demand) investments
Capacity price mechanisms

**Pay for demonstrated, dependable capacity:**

- Ensure resource adequacy
- Provide forward prices (years) for long-term investment, supply “missing money”
- Technology agnostic, and may reflect specific essential reliability support services i.e., ramping

Dependable capacity can be assessed as Effective Load Carrying Capacity (ELCC) as VREs increase

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*Challenge: No one-size-fits all ... Existing system matters*
Essential reliability support services

Variable renewable energy (VREs), namely inverter-based resources don’t provide the same system services as rotating equipment:

- Operating Reserves: primary, secondary, tertiary (frequency response, spinning reserves and supplemental reserves)
- Fast frequency response products
- Ramping products
- Reactive power & dynamic voltage support
- Inertial response
- Black start and restoration

Serving net load with high penetrations of renewables

Traditional ancillary services must be expanded

*GW/h ERCOT, 6GW/hr CAISO
Power market design to support the energy transition

*Ensure reliability, stability and resilience and drive system efficiencies*

- Incentivize performance at both the system and plant level
- Incentivize needed plant characteristics to provide additional support services: fast ramping, fast frequency response, etc.
- Pay for needed plant investments to ensure longer-term system adequacy
- Promote cross sector coupling, T&D expansion, distributed energy resources and active demand-side management with prosumer participation and consumer protection
Building a world that works